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(12) **United States Patent
Langston**(10) **Patent No.: US 6,553,239 B1**(45) **Date of Patent: *Apr. 22, 2003**(54) **LOW POWER, SHORT RANGE
POINT-TO-MULTIPOINT
COMMUNICATIONS SYSTEM**

3,836,973 A	9/1974	Shnitkin et al.
4,295,141 A	10/1981	Bogner
4,384,367 A	5/1983	Kine et al.
4,498,084 A	2/1985	Werner et al.

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(List continued on next page.)

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(US)****FOREIGN PATENT DOCUMENTS**(*) **Notice:** Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

DE	1823794	9/1931
DE	1586260	3/1981
DE	88302180	3/1987
EP	0201254	11/1986
EP	282347	9/1988

(List continued on next page.)

This patent is subject to a terminal disclaimer.

OTHER PUBLICATIONS(21) **Appl. No.: 09/626,971**(22) **Filed: Jul. 27, 2000****Related U.S. Application Data**

(60) Continuation of application No. 09/481,054, filed on Jan. 11, 2000, now Pat. No. 6,112,056, which is a division of application No. 08/477,031, filed on Jun. 7, 1995, now Pat. No. 6,006,069.

(51) **Int. Cl.⁷ H04B 1/38; H04M 1/00**(52) **U.S. Cl. 455/562; 455/103; 343/778;
343/824**(58) **Field of Search 455/62, 63, 67.1,
455/25, 101, 103, 60, 422, 517, 524, 561,
562, 41; 343/853, 797, 891, 890; 348/6;
342/361, 362, 363, 364, 365, 366**(56) **References Cited****U.S. PATENT DOCUMENTS**

1,823,794 A	9/1931	Esau
2,901,599 A	8/1959	Leyton
2,992,427 A	7/1961	Franco
3,144,647 A	8/1964	Sichak
3,735,266 A	5/1973	Amitay
3,813,483 A	5/1974	Kurosawa et al.

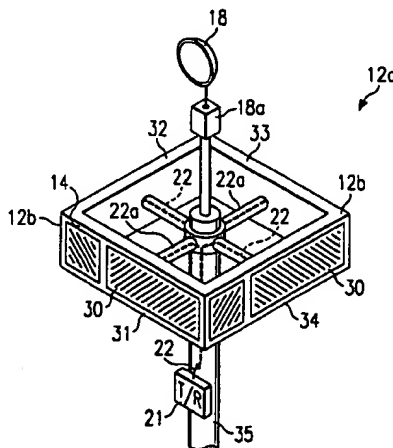
Shindo, Shuichi, et al., "Radio Subscriber Loop System for High-Speed Digital Communications," IEEE 1981, (0536-1468/81/0000-0348) pp. 66.1.1-66.15.

Murakami, Masatoshi, et al., "A Multiple Access Digital Microwave Radio System for Local Subscribers," IEEE 1983. (83CH1874-7/83/0000-0380). pp. B2.5.1-B2.5.7. Manichaiku, Yongyut, et al. "RAPAC—A Point-to-Multi-point Digital Radio System for Local Distribution," IEEE 1983. (83CH1874-7/83/0000-1013). pp. D4.2.1-D4.2.4.

(List continued on next page.)

Primary Examiner—Vivian Chin**Assistant Examiner**—James K Moore(74) **Attorney, Agent, or Firm**—Baker Botts L.L.P.(57) **ABSTRACT**

A point-to-multipoint or two-way communications system is provided by a nodal transmitter located in a node with a plurality of nodal antennas radiating different polarization signals about the node. The system includes subscriber stations with directional antennas adapted to receive signals radiated from the nodal transmitter. The system may additionally include capability for transmitting and radiating subscriber signals to the nodal transmitter location for two-way communications.

20 Claims, 7 Drawing Sheets

U.S. PATENT DOCUMENTS

4,513,293	A	4/1985	Stephens	
4,528,656	A	7/1985	Morais	
4,571,621	A	2/1986	Dalimonte et al.	
4,589,108	A	5/1986	Billy	
4,633,463	A	12/1986	Mack	
4,642,806	A	2/1987	Hewitt et al.	
4,647,942	A	3/1987	Counselman, III et al.	
4,651,330	A	3/1987	Ballance	
4,658,405	A	4/1987	Yazuka et al.	
4,670,889	A	6/1987	Hewitt	
4,704,733	A	11/1987	Kawano	
4,747,160	A	5/1988	Bossard	
4,750,036	A	6/1988	Martinez	
4,825,222	A	4/1989	Butcher	
4,965,825	A	10/1990	Harvey et al.	
5,212,830	A	5/1993	Miller	
5,303,229	A	4/1994	Withers et al.	
5,373,502	A	12/1994	Turban	
5,444,762	A	8/1995	Frey et al.	
5,594,937	A	1/1997	Stiles et al.	
5,694,134	A *	12/1997	Barnes	343/700 MS
5,767,814	A	6/1998	Conroy et al.	
5,771,449	A	6/1998	Blasing et al.	

FOREIGN PATENT DOCUMENTS

EP	429200	5/1991
EP	577959	1/1993
EP	572171	12/1993
FR	1024523	9/1950
WO	9525409	9/1995

OTHER PUBLICATIONS

Reference Data for Radio Fifth Edition Engineers: "Electromagnetic-Wave Propagation" Fifth Edition, Howard Sams & Co., Inc., Mar. 1970. p.26-29.

Siukola, M.S. "Is Circuitry Polarized TV Coming?", IEEE Transactions on Broadcasting, vol. BC-21. No. 1. Mar. 1975, pp. 1-6.

Siukola, M. S., "Size and Performance Tradeoff Characteristics in Multiple Arrays of Horizontally and Circularly Polarized TV Antennas," IEEE Transactions on Broadcasting, vol., BC-22. No. 1, Mar. 1976. pp. 5-12.

Siukola, M.S., "Evaluation of Circularly Polarized TV Antenna Systems," IEEE Transactions on Broadcasting, vol. BC-24, No. 1, Mar. 1978. pp. 14-19.

Funkschau, "Magazine for Radio and Television Technology, High-Fi, Electronics and Microcomputers," Issued 51, Feb. 2, 1979, pp. 1-15 (Translation).

IEEE Conference Publication 191 (Dec. 1980) Emmett, J. R., "Distributing Digital Video," Phillips, G.J., "How will broadcast programs reach the home in the future?", "Special Report LPTV," Feb. 23, 1981.

Barnes, B. C., et al., "Technology for A 29 GHZ Local Distribution Radio," RAI International Congress Centre, Amsterdam, The Netherlands, Sep. 1981. pp. 119-125.

Lapin, S.P., Television Broadcasting at Microwave Frequencies, IEEE Transactions on Broadcasting, vol. BC-27, No. 3. Sep. 1981, pp. 54-59.

Pilgrim M., "Local Network Microwave Links at 29 GHz," British Telecom Research Laboratories. Sep. 1982, pp. 225-228.

Simpson, W.G., "Digital Television Networks," IEE Proc., vol. 129, Pt. A, No. 7, Sep. 1982. pp. 427-435.

Mohamed, et al., "29 GHz Radio Systems for Local Distribution Network," Finlandia Hall, Helsinki, Finland, Sep. 1982, pp. 709-714.

Jacobs, George, "Low-Power Television: short-range, low-cost TV Stations Are in the Offing as the FCC Prepare to Establish Broadcast Requirements," Large Systems Communications, Jun. 1982. pp. 54-59.

"Broadcasting-Satellite Systems," By International Radio Consultative Committee; International Telecommunication Union (Geneva, 1983).

Gross, L.S., *The New Television Technologies*. Wm. C. Brown Company Publishers. ISBN 0-697-04362-2, pp. 77-78.

Shindo, S., et al., TDMA for Radio Local Distribution System. IEE 1983 (83HC1874-7/83/0000-0370), pp. B2.3.1-B2.3.5.

Manichaikul, Y., "Characterisation of the User Demand and Capacity Requirement in a Multiserve Environment for RAPAC Digital Termination System," IEEE 1983, (83CH1874-7/83/0000-1030), pp. D4.5.1-D4.5.6.

Meinel, Holger, et al., "A 40 GHz Railway Communication System," IEEE (0733-8716/83/0900-0615). pp. 616-622.

Shindo, et al., "Radio Local Distribution System for High-Speed Digital Communications," IEEE Journal on Selected Areas in Communications, vol. SAC-1, No. 4, Sep. 1983.

Dupuis, Philippe, et al., "Millimeter Wave Subscriber Loops," IEEE Journal on Selected Areas in Communications, vol. SAC-1. No. 4. Sep. 1983.

Silverman, D., "The Digital Termination Systems Solution for High Speed Local Distribution," Microwave Journal. (Jan. 1983).

Cooper, et al. "Cellular Mobile Technology: the Great Multiplier," IEEE Spectrum, Jun. 1983.

"Forward Millimeter Wave Communications Systems," IEEE Journal (Sep. 1983).

Hewitt, M. T., "A Cost Effective 19 GHZ Digital Multipoint Radio System for Local Distribution Applications," IEEE 1984. (CH 2028-9/84/000-0959).

"Channel Master Microbeam System and SMATV Plants/Part Seven," Coop's Satellite Digest (Sep. 1984).

Dooi, et al. "A 50 GHZ Band Millimeter-Wave Radio System," IEEE/Eisevier Science Publishers B.V. (North Holland) 1984.

Ogawa, et al. "A 26-GHz high-performance MIC Transmitter/Receiver for Digital Radio Subscriber Systems," IEEE Transactions on Microwave Theory and Techniques, vol. MTT-32, No. 12, Dec. 1984.

Mohamed, et al., "29 GHZ Point-to-Point Radio Systems for Local Distribution," Br. Telecom Technical Journal, vol. No. 1. Jan. 1984.

McGraw-Hill Dictionary of Scientific and Technical Terms, Third Edition (1984).

Bell, T.E., *The new Television: Looking Behind the Tube*, IEEE Spectrum (Aug. 1984).

Mohamed, et al., "19 GHz Digital Point-to-Multipoint Radio System for Local Distribution," ICC85, Chicago. Jun. 23-26 1985.

Nakayama, et al., "26 GHz Band Digital Subscriber Radio System (26SS-D1) for High-Speed Digital Communications" IEEE 1985.

Hawkins, et al., "Path Loss Characteristic of 60 GHz Transmissions," Electronic Letters. vol. 21. part 22. Oct. 1985.

- O'Hara, S., "The EVolution of a Modern Telecommunications Network to the Year 2000 and Beyond." IEE Proceedings vol. 132 Pt. A. No. 7. Nov. 1985.
- Reference Data for Engineers: Radio, Electronics, Computer and Communications, Howard Sams & Co., Inc. Seventh Edition. 1985.
- Yamada, et al., "High Capacity Subscriber Radio," IEEE 1986, (CH2314-3/86/0000-1758).
- Roome, S.J. "Bibliography on Propagation Factors Affecting Microwave Links Operating in the 10 GHz to 30 GHz Frequency Range." IEE Proceedings. vol. 133, Pt. H. No 1. Feb. 1986.
- "Recommendations and Reports of the CCIR." International Telecommunication Union (International Radio Consultative Committee) Geneva, 1986.
- Evans, W.E., "MMDS Technology—An International Opportunity" IEE Conference Publication 268, Feb. 1987.
- Blake, R.G., "The Use of Millimeter-Waves for Broadband Local Distribution," 17 European Microwave Conference Sep. 1987.
- Bailey, et al., "A Multipoint Radio for Local Networks," IEEE 1987.
- Brindley, Keith, "The Electromagnetic Wave Spectrum, The Ionosphere, and Radio Wavebands," *Radio and Electronics Engineer's Pocket Book* 1987.
- Pilgrim, et al., "M³VDS—The Cheapest, Quickest, and Least Obtrusive Means of Providing Multichannel Domestic," International Broadcasting Convention 1987.
- Meinel, H.H., "Millimeter-Wave Systems and Applications in Europe." IEEE 1988.
- Ogawa, et al., "A 50-GHz Compact Communication System for Video Link Fabricated in MIC," IEEE 1988.
- Pilgrim, et al., "MM-Wave Direct-to-Home Multichannel TV Delivery System," British Telecom Research Laboratory, IEEE 1989.
- Ulrich, et al., "Digital Termination Systems." pg.20
- Tallarida, R., Mathematics, Symbols, and Physical Constants (Classification of Electromagnetic Radiation and Conversion Constants and Multipliers). *The Electrical Engineering Handbook*, 1993.
- Weinstein, *Getting the Picture—A Guide to CATV and the New Electronic Media*, Chapter 8. "Multipoint Distribution Service (MDS)", IEEE Press. Mar. 1996. pp. 155-160.
- Daniel, et al., *Propagation*, McGraw-Hill, 1986, pp. 6.1-8.22.
- Table Division, nomenclature, and allocations of microwaves*. Copyright by Artech House, Inc., Mar. 25, 1996.
- Pilgrim, M., "Millimeter-Waves Applied to TV Distribution," British Telecom Research Laboratories, IPSWICH IP5 7RE.
- Forbes ASAP, "George Gilder's Telecosm—The New Rule of Wireless."
- Pozar, David, M., "A Reciprocity Method of Analysis for Printed Slot and Slot-Coupled Microstrip Antennas," IEEE Transactions on Antennas and Propagation, vol. AP-34, No. 12 Dec. 1996, pp. 1439-1449.
- Buus, R., "Electronics Designer' Handbook," McGraw-Hill Book Company, Second Edition, Mar. 1996.
- S. A. Mohamed and M. Pilgram, "29 GHz Point-to-Point Radio Systems for Local Distribution," British Telecom Technol. Journal, vol. 2, No. 1, Jan. 1984.
- S.W. Seetharam, G. J. Miden, J. B. Evans, "A Pipelined Architecture to Map ATM Cells to 622 Mb/s SONET OC-12 Payloads," *Institute of Electrical and Electronics Engineers*, vol. 3, May 30, 1994, pp. 245-248.

* cited by examiner

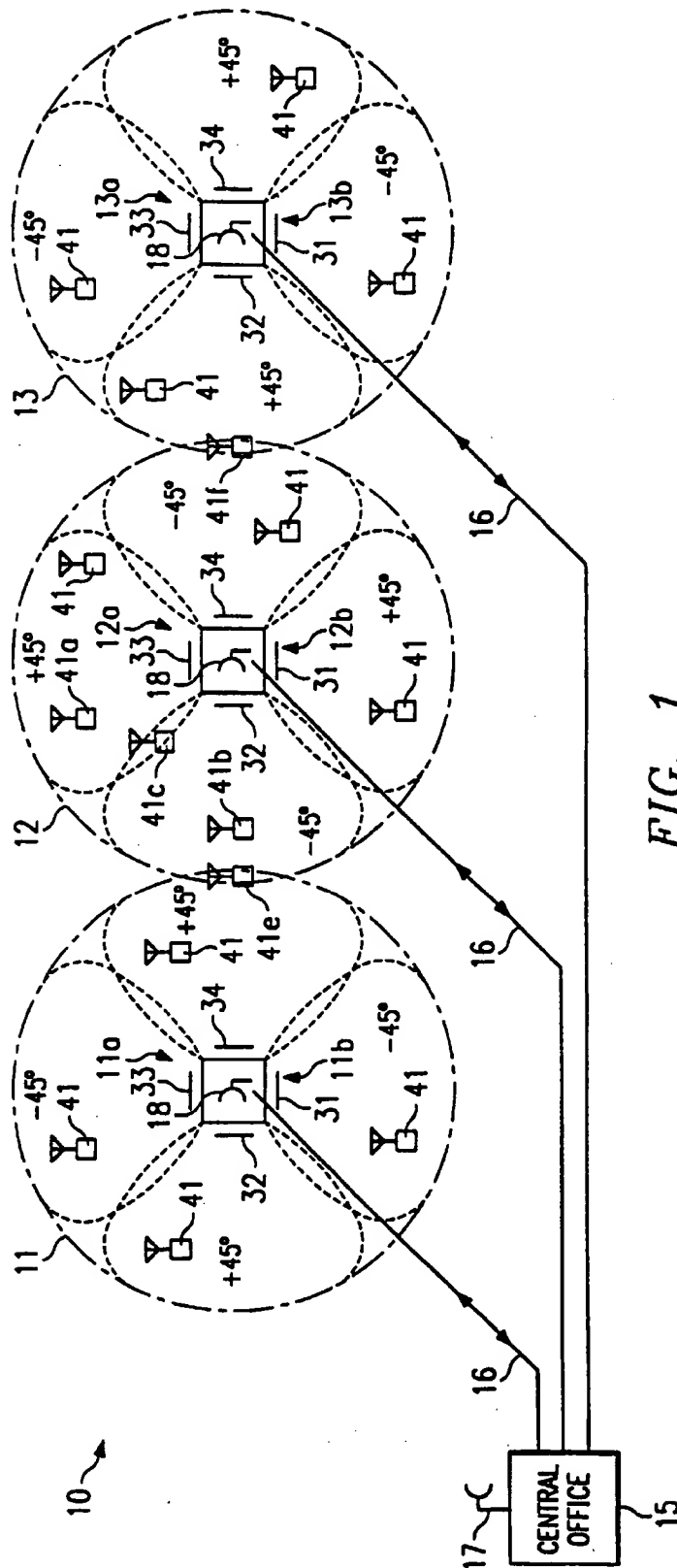


FIG. 2

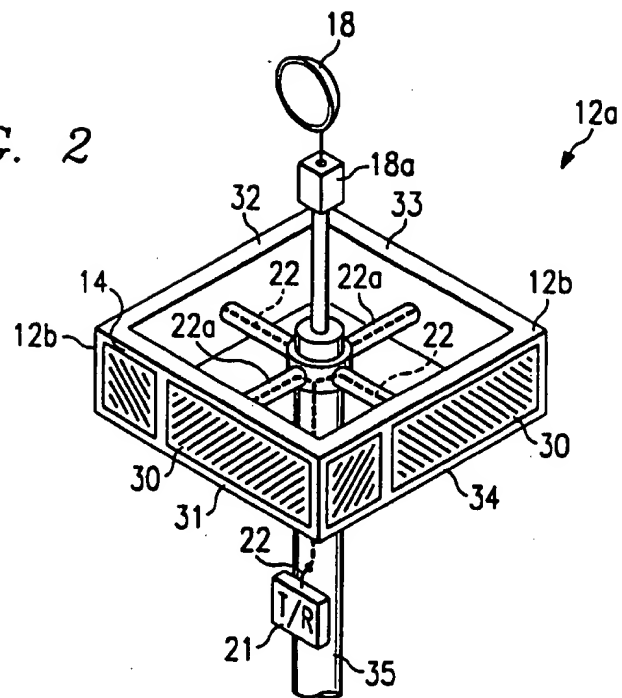
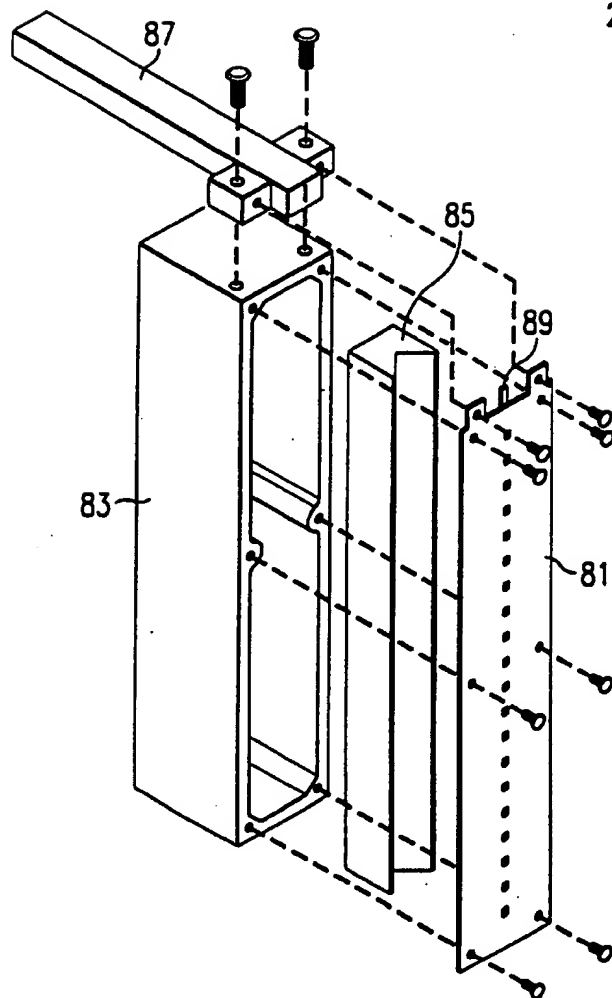


FIG. 3



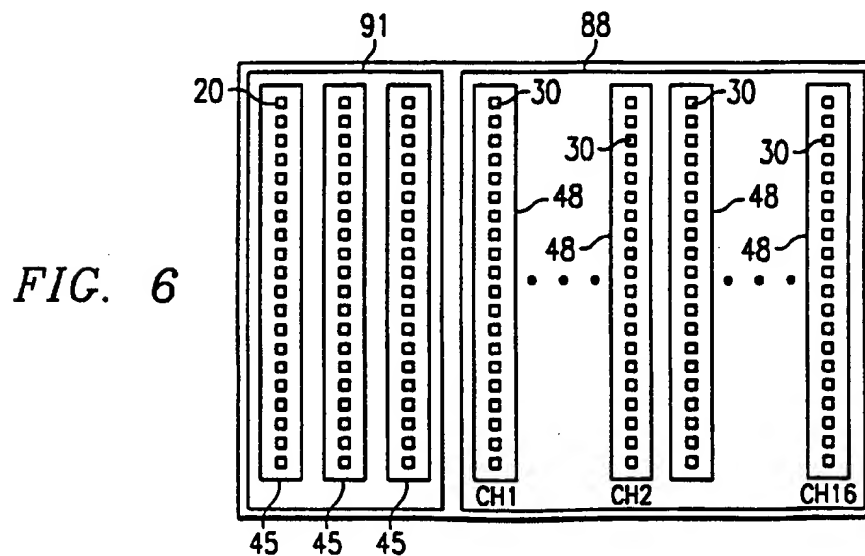
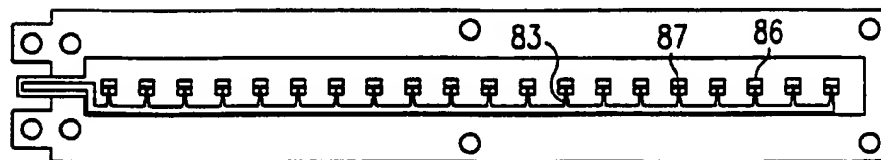
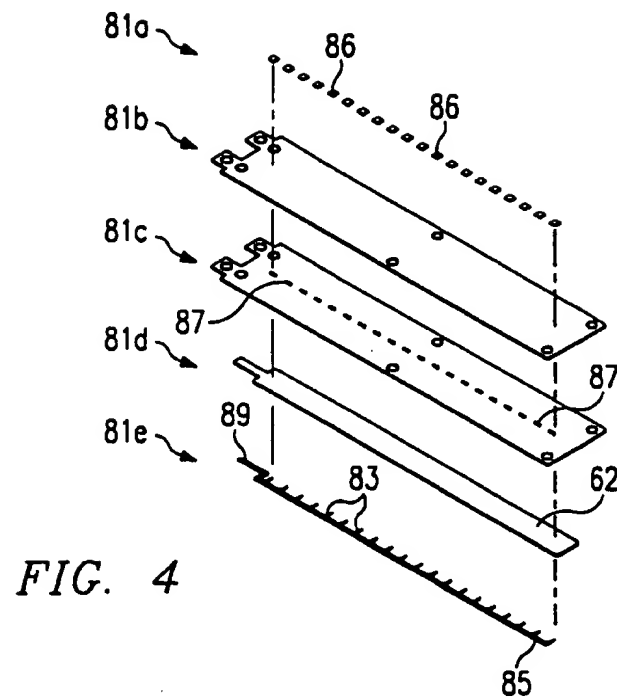


FIG. 7

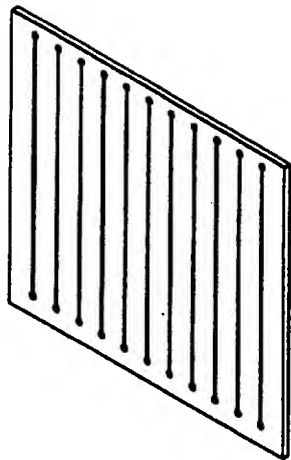
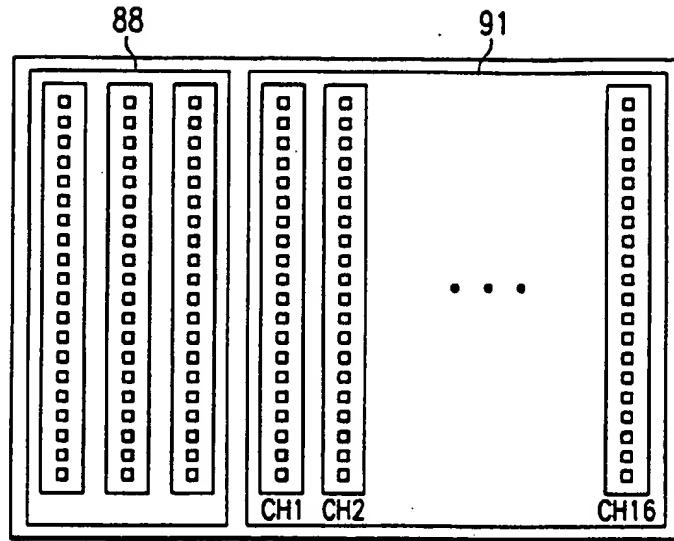


FIG. 8A

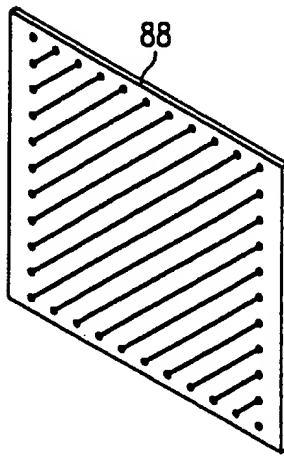


FIG. 8B

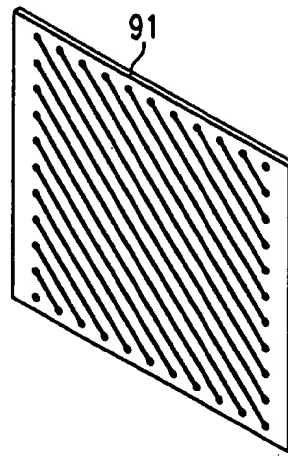


FIG. 8C

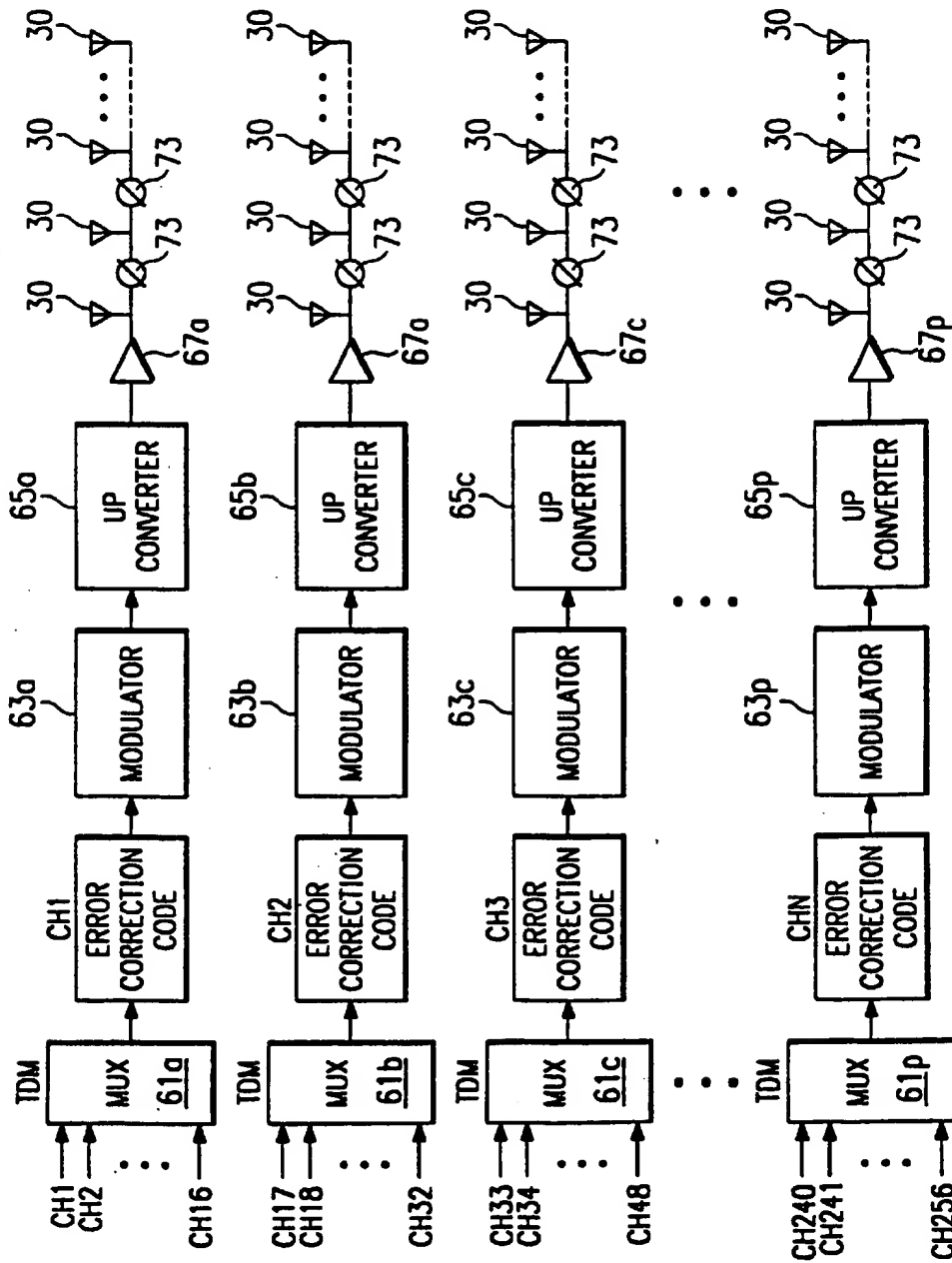


FIG. 9

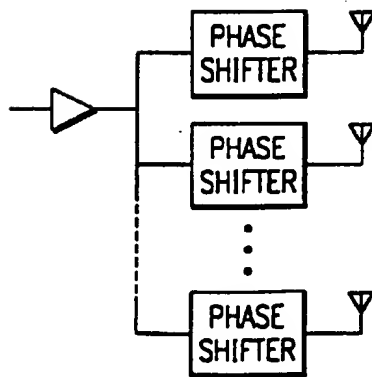


FIG. 10

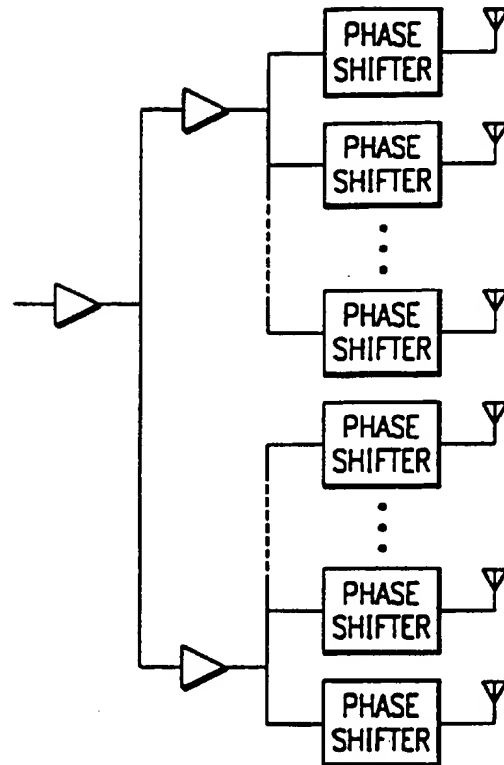


FIG. 11

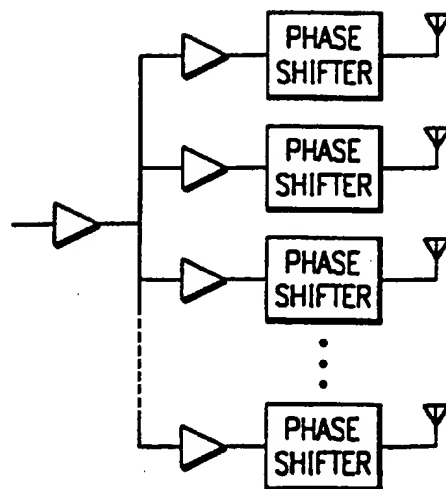


FIG. 12

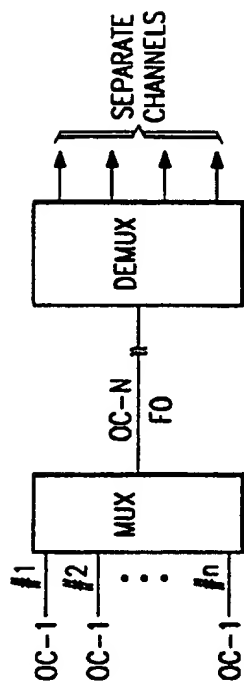


FIG. 13

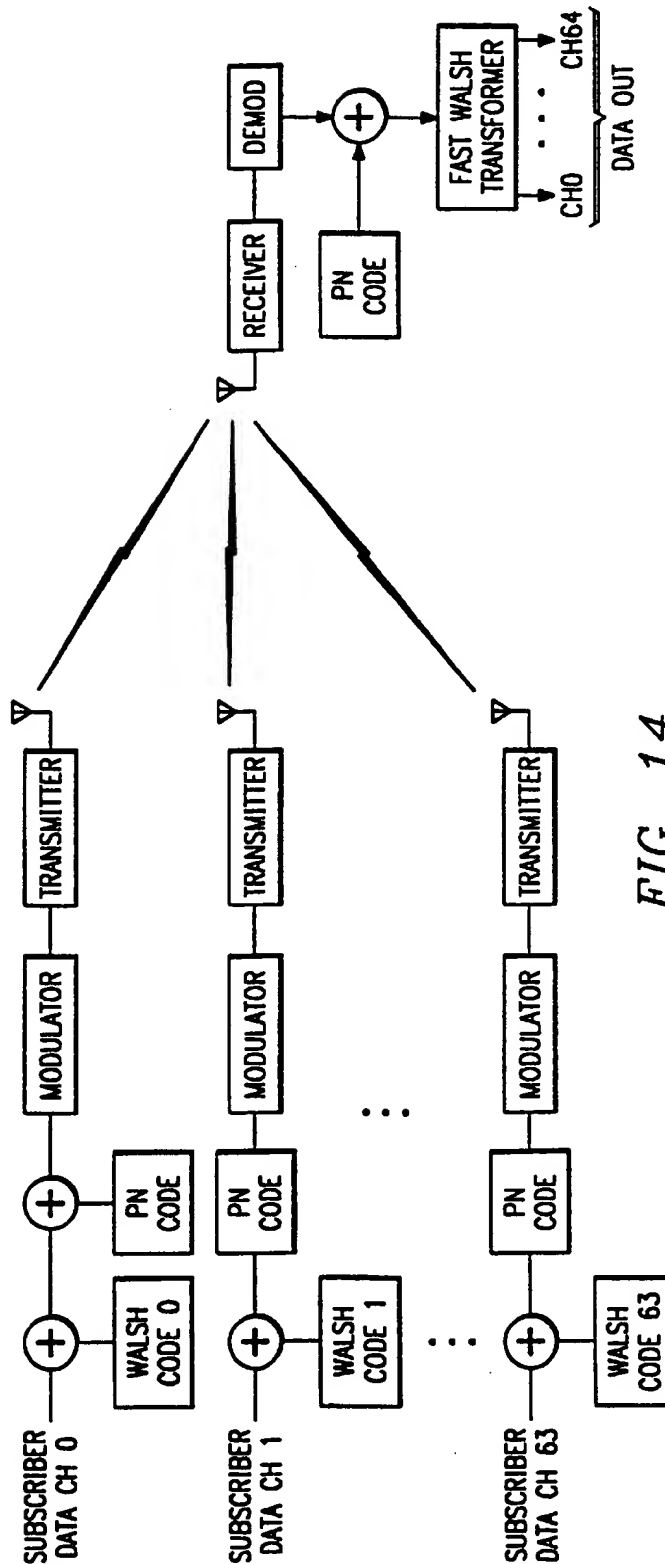


FIG. 14

1

LOW POWER, SHORT RANGE POINT-TO-MULTIPOINT COMMUNICATIONS SYSTEM

RELATED APPLICATION

This application is a continuation of U.S. application Ser. No. 09/481,054, filed Jan. 11, 2000 now U.S. Pat. No. 6,112,056 which is a divisional of U.S. application Ser. No. 08/477,031 filed Jun. 7, 1995, now U.S. Pat. No. 6,006,069

TECHNICAL FIELD OF THE INVENTION

This invention relates to point-to-multipoint delivery of communication services and more particularly to broadcast systems operating in the millimeter frequency range.

BACKGROUND OF THE INVENTION

Communication systems operating over a wide range of frequencies, modulation techniques, multiplexing techniques, error correction techniques, protocols, and network topologies are known in the state-of-the-art. Many recent papers have described numerous techniques for wireless transmission of two-way, switched narrowband services (e.g., TDMA time division multiple access) cellular, TDMA PCS (personal communication system), CDMA PCS (Code Division Multiple Access), etc. Many military systems such as JTIDS (Joint Tactical Information Distribution System), SINCGARS (Single Channel Ground and Airborne Radio System), PLRS (Position Locating and Report System), and MILSTAR (a military satellite communication system) have shown that wireless transmission can provide integrated voice and data services. It has been proposed that some form of television distribution or communication distribution systems may be provided by utilizing devices in the millimeter wave frequency band, which is between 28 GHz and 300 GHz using short range cellular transmitters covering small areas which are fed, e.g., by an underground cable in a manner similar to cellular radio. This distribution may also be made using microwaves converted at the local stations to the millimeter waves for local distribution. The distribution to millimeter wave stations may also be done by a fiber optic system or satellite distribution system.

A discussion of millimeter wave stations appears in the IEEE Spectrum of June 1982, pages 54-59, entitled, "Low-Power Television-Short Range, Low Cost TV Stations are in the Offing as the FCC Prepares to Establish Broadcast Requirements." U.S. Pat. No. 4,747,160 entitled, "Low Power Multi-function Cellular Television System" of Bossard describes a low power, point to multipoint cellular television system operating in the 27.5 to 29.5 GHz frequency band with Omni-directional antennas. A 29 GHz point-to-point radio system for local distribution is described e.g., the British Telecom Technical Journal, vol. 2, no. 1, January 1984, entitled, "29 GHz-Point-to-Point Radio Systems for Local Distribution" by S. A. Mohamed and M. Pilgrim.

It is highly desirable to provide some means to deliver improved broadband, wireless point-to-multipoint distribution service in millimeter frequency range.

SUMMARY OF THE INVENTION

In accordance with one preferred embodiment of the present invention, a low power, short range, wireless point-to-multipoint communication system is provided by a nodal transmitter located in a given node and a plurality of uni-directional transmitting antennas coupled to said trans-

2

mitter are positioned to radiate in different directions from the node and about the node. The uni-directional antennas being of polarization types such that the polarization of the transmitted signal alternates about the node. A plurality of subscriber stations about the node have receiving antennas polarized to receive signals from a selected one of the uni-directional antennas.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates the system according to one embodiment of the present invention;

FIG. 2 illustrates a nodal broadcast system in FIG. 1;

FIG. 3 illustrates an assembly view of a linear array according to one embodiment of the present invention;

FIG. 4 illustrates layers of patch antenna array of FIG. 3;

FIG. 5 illustrates a composite sketch of the patch antenna of FIG. 4;

FIG. 6 illustrates one panel antenna according to one embodiment of the present invention;

FIG. 7 illustrates a second panel antenna for transmitting and receiving polarization orthogonal to that in FIG. 6;

FIGS. 8A-C illustrate the polarizers;

FIG. 9 illustrates the time multiplexing system according to one embodiment of the present invention;

FIG. 10 illustrates a common amplifier for all elements of a linear array;

FIG. 11 illustrates an amplifier tree feeding the element of an array;

FIG. 12 illustrates separate antenna for each elements;

FIG. 13 illustrates multiplexing DC-1 signals; and

FIG. 14 illustrates code division multiplexing.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. 1, there is illustrated the distribution system network 10. This network comprises a plurality of nodes, such as node 11 through 13 covering a given combined area. For example, this area may cover a few city blocks only, but with hundreds of such nodes the area may comprise an entire large city. A central office 15 would be, for example, the central message center or source of programming for distribution to the other nodes 11 through 13. Each of the nodes would include a nodal broadcast transmitter or transmitter and receiver system. This is represented by systems 11a, 12a, and 13a in the center of the nodes 11 through 13. The transmission from the central office 15 to the nodal broadcast transmitter systems 11a, 12a, or 13a may be done by cabling in or around the city such as fiber optic telephone exchange cables represented here as cable 16 between the central office 15 and the node transmitter systems 11a, 12a, and 13a. This coupling may also be done using microwave antennas such as using antenna 17 from the central office 15 communicating with antennas 18 at the center of the nodes at the systems 11a, 12a, or 13a. This distribution may be implemented in a variety of other configurations well known in the state of the art.

Referring to FIG. 2, there is illustrated a sketch of a nodal broadcast transmitter or system 12a. In the case of microwave distribution from a central office, there is the microwave antenna represented schematically by 18. The nodal transmitter broadcast systems 11a and 13a are like system 12a illustrated in FIG. 2, but with the polarizations indicated in the sketches as +45° rotation and -45° (315°) rotation of FIG. 1. (Other orthogonal polarization may be used, e.g.,

vertical and horizontal polarization). The system 12a includes a post 35 for supporting a four-quadrant sectorized antenna complex system represented by 12b. The system 12a includes a transmitter and receiver represented schematically by 21. Signals transmitted from system 12a are coupled from transmitter 21 to the nodal transmitter coverage or broadcast antenna system 12b comprised of four panel array antennas 31, 32, 33, and 34 via leads 22. The panel antennas 31-34 are mounted to post 35 via supports 22a housing transmission lines 22. Each of these panel antennas 31-34 comprises an array of transmitting antenna elements and receiving antenna elements as will be discussed in more detail later. Polarization of these antenna elements 30 for antenna system 12b is such that panels 31 and 33 for system 12b transmit 45° slant polarized waves (marked +45° in FIG. 1), while panels 32 and 34 for system 12b transmit -45° (315°) slant polarized waves (marked -45° slant in FIG. 1). See FIG. 1. A more detailed description of these panel antennas follows in connection with later figures.

These panel antennas, for example, produce a 90 degree beam width so that each of the panel antennas 31-34 covers approximately 90 degrees beam width and the polarization from these panel antennas 31-34 alternates from +45° slant polarization to -45° slant (315°) polarization to +45° slant polarization and then to -45° (315°) polarization about the center of the node on post 35. This, therefore, provides a 360 degree pattern about the center of the node where the node broadcast transmitter is located.

The adjacent nodes 11 and 13 on either side of node 12 present orthogonal polarization. For example, the panel antennas 31 and 33 in nodes 11 and 13 produce -45° (315°) polarized signals and the panel antennas 32 and 34 in nodes 11 and 13 produce +45° polarized signals. Therefore, at the 10 adjacent sectors of the nodes, that is where node 11 is adjacent to node 12, the polarizations are orthogonal, and where node 12 meets node 13 the polarization is orthogonal. The node broadcast transmitting antennas systems 11b, 12b and 13b transmit and communicate with receiving stations 41 scattered in the area of the nodes.

Receiving station 41 may be located anywhere in any of the nodes 11-13 and will receive the signal radiated from the antenna complex at the center of one of the nodes from the sectorized antenna system 20. The polarization of the receiving station 41 would determine which sector it is receiving from. For example, the receiving station 41a in FIG. 1 in node 12 would be in the +45° slant polarized sector and receive +45° slant polarized signals from the panel antenna 33 of system 12b. Station 41b in node 12 would receive preferably -45° (315°) slant polarized signals from the panel antenna 32 and not +45° polarized signals from panels 31 or 33 from system 12b or from panel 34 of system 11b. For the receiving antenna 41c, located in the overlapping area of the pattern of 32 and 33, it is possible to receive both +45° polarized signals from panel antenna 33 and -45° (315°) slant polarized signals from panel antenna 32. However, a signal received from the face which is of the wrong polarization from the antenna 41 would, be 20 to 30 db lower in power than the other face. For example, if the antenna of 41c was -45° (315°) polarized it would receive the signal from panel antenna (+45° polarized) 33 of system 12b from 20 to 30 db down from that of the -45° (315°) polarized signal from antenna 32 of system 12b. Similarly, stations 41e and 41f at the edges of nodes 11 and 12 and 12 and 13, respectively, achieve similar isolation based on polarization. That is, station 41e with a -45° (315°) polarized antenna picks up signals from panel antenna, 32 of system 12b. The

signals from panel antenna 34 of system 11b are 20 to 30 db lower than those from panel antenna 32 of system 12b.

The system is designed such that the signals from all four panels 31-34 are transmitting at the same carrier frequencies but may contain different information. The system is dependent upon space (different coverage areas) as well as frequency and polarization diversity.

The system, as described herein, utilizes a four-quadrant sectorized antenna. However the system could be of any even number of sectors such as two, four, eight, etc. The four-quadrant sectorized antenna discussed in FIG. 1 has an azimuth pattern relatively flat over a plus and minus 45 degrees from the center (90° beam width) which is easy to implement and is, therefore, more easily implemented, for example on a building or a tower for mounting panel antennas. An octagon, or eight sector, antenna system may be practical in some cases, but receivers located a line drawn to the corners will be able to see more than two panels and, hence, see signals having the same polarization. Thus, the four sector is the preferred embodiment where frequency re-use is required.

The transmission to and from the central office 15, as stated previously, may include a microwave network with the microwave dish 18 coupled to a transceiver via an up/down converter 18a. The received signals from the central office 15 are upconverted to millimeter waves and sent via the panel antennas and the received signals at the panel antennas are down converted to microwave frequencies and sent back to the central office 15 via antenna 18 or cables 16. (Other frequencies, e.g., millimeter frequency, may also be used to interconnect the nodes).

It is highly desired in accordance with the present invention that the elevation angle of the node antenna beam be in the order of 10 degrees. This is achieved in each of the panel antennas by linear arrays of antenna elements as shown in FIGS. 3-6. Referring to FIG. 3, each linear array 30 includes a patch antenna array 81 mounted on conductive housing 83. A back lobe absorber 85 is placed behind the patch array 81. The millimeter waves are coupled by a millimeter waveguide 87 to the patch array 81. A probe 81 passes through an insulated opening in the waveguide to transition to a microstrip line of the patch antenna.

Referring to FIG. 4, there is illustrated the layers of the patch antenna array 81. The outboard layer 81a is layer 1 comprising 20 conductive radiating patches 86. The patches are 0.007 inch copper and are 0.1x0.12 in on 0.278 inch centers. Behind layer 81a is layer 81b which is 0.015 thick dielectric. Layer 81c is a 0.007 inch copper layer with 0.070x0.006 inch slots 87 on 0.278 centers with a slot aligned behind each patch. Layer 81c is on opposite surface of dielectric layer 81b with respect to layer 81a. Layer 81d is a dielectric layer between the slot radiator of layer 81c and the radiators of layer 81e. Layer 81d is 0.10 in. thick with an aperture 62 cut out over the slot area. Layer 81e is a 0.0007 inch copper line with 20 exciter stubs 83 aligned with the slots and the patches. The stubs 83 are connected to each other via a conductive line 85 with the spacing between the stubs controlling the phase (phase shifter) between the radiating elements. The one end 89 of the line forms the coupling probe for the waveguide. An illustrated composite sketch is shown in FIG. 5 with housing. The stubs 83 are behind and cross slots 87 and the slots are behind the patches 86. This antenna array provides horizontal linear polarization. For additional information on an antenna similar to this, see "A Reciprocity Method of Analysis for Printed Slot and Slot Coupled Antennas" by David Pozar in IEEE

Transactions on Antennas and Propagation, vol. AP-34, no. 21. The printed circuit antenna panels 31 and 33 for 12b may each be like that shown in FIG. 6 with 16 linear arrays 48 for 16 transmitter carrier channels (ch1–ch16 for 27.86 GHz to 28.50 GHz or channel 1–16 for 28.50 GHz to 29.5 GHz). Each panel antenna 31–34 covers the frequency band from 27.5 GHz to 28.5 GHz or 28.5 GHz to 29.5 GHz. In accordance with the preferred embodiment with 45° slant polarization, a polarizer layer 88 (shown in outline in FIGS. 6 and 7) is placed over the 16 linear arrays 48 to produce +45° slant polarization. The polarizer layer 88 has a vertical grid on in board surface and a 45° grid on the outboard surface layer as shown in FIGS. 8A–C. On the left most part of the antenna panels are three receiving linear arrays 45 operating over a frequency band of 27.5–27.64 GHz or 29.38–29.5 GHz. There are three different 40 MHz wide receiving channels in this band. These may be used for telephony. The receiving linear arrays 45 also have a polarizer layer 91 but with outboard grid rotated in the 315° direction or –45° to rotate the polarization orthogonal. The panels 31 and 33 at nodal system 12a use the polarizers as shown in FIG. 6 and the panels 32 and 34 use the polarizers 88 and 91 reversed as shown in FIG. 7. The antenna pattern may be tailored (shaped) to provide desired radiator pattern. The same panel antenna could be horizontal and vertical dipoles. The patch antennas could provide horizontal and vertical polarization by not placing polarizer layer over the patch antenna for horizontal polarization and an additional layer over the +45° layer to produce vertical polarization.

In applicant's preferred embodiment herein, the stations 41 include transceivers which receive the broadcast RF carrier channels (ch1–ch12 for service provider 1) and can transmit back to the systems 11a, 12a, or 13a on the return carrier frequencies 27.5–27.62 for service provider 1. The receive array polarization on the panels are orthogonally polarized with respect to the transmit arrays. In this manner, there is special, as well as polarization and frequency isolation, between the transmit and receive antennas on the panels. There could also be a linear array of 20 dipoles for each of the 16 RF transmitter carrier channels and each receiver channel. Each linear array for each channel could comprise 20 dipoles which are fed by conductive pairs as dipoles forming vertical dipole antennas. Adjacent in a horizontal plane could be horizontally polarized dipole elements. These panels include a reflective surface 37 behind the dipoles to form a uni-directional antenna that radiates generally a fairly uniform pattern over a 90 degree beam width.

In accordance with the present invention as represented by FIG. 9, the channel information from 16 video channels is time multiplexed at multiplexers 61a–61p and applied to each RF carrier channel 1 through channel 12. Each of these 16 video channels is provided at a 3 MBS (megabits per second) rate, so for the 16 video channel the rate is 48 MBS. These are separately modulated using e.g. a QPSK (Quadrature Phase Shift Keying) modulator (63a–63p) and separately up converted at converter (65a–65p) to the millimeter frequency and power amplified at separate amplifiers 67a–67p and applied to a given linear patch antenna array of the 20 patches as illustrated in FIGS. 3–6. A Forward Error Correction (FEC) code is applied by placing an encoder before each modulator. In this manner each information channel is modulated onto a low frequency RF carrier and up converted by upconverter 65 to the final millimeter frequency and amplified by a dedicated power amplifier 67 and applied to the antenna array for that carrier channel (1–12). In this approach, all the amplifiers power goes to a narrow,

single band carrier. The linearity requirements on the amplifier are much reduced since it must only meet the linearity requirements of the narrow 60 MHz channel frequency band signal being transmitted, e.g., the amplifier can be operated in saturation for FM or near saturation for Quadrature Phase Shift Keying (QPSK). It is extremely important that the power amplifier operate in a linear mode to prevent interference between channels caused by intermodulations distortion; therefore, this system of multiple low power transmitters operating in amplification and modulation over very narrow frequency bands and using separate antennas and combining the outputs in space accomplish the low intermodulation distortion according to the present invention.

In order to form the narrow vertical antenna pattern, it is necessary that the linear array be phased in a proper proportion between each of the 20 radiating patches 30, and this is accomplished by phase shifters 73 between the amplifiers 67 and the antenna radiators 30 as represented in FIG. 9. One amplifier 67 may be used for all twenty radiators 30 of a linear array as shown in FIGS. 10 and 12, or two amplifiers as shown in FIG. 11—one for each ten radiators. The amplification preferably is done as illustrated in FIG. 12 with amplifiers for each of the antenna radiators 30 separately. The amplification may also be done by power dividers dividing up the signal to amplifiers and then combining the signals. The phase shifts can be adjusted by the distance between the stubs 83 of FIG. 4.

Analog modulation techniques pose certain problems for Local Multipoint Distribution Services, or LMDS. Although FM techniques have been shown to be effective in multi-path environments as well as provide good video Signal-to-Noise (S/N) when employed for LMDS applications, FM is very inefficient in terms of spectrum utilization. A single NTSC video channel will use 18–30 MHz of spectrum to achieve the desired signal to noise improvement. Another advantage of FM is the "capture effect", i.e., its ability to suppress other signals which are below some threshold level although the interference may be on the same frequency. AM is more efficient in terms of bandwidth, but requires much higher receiver Carrier-to-Noise (C/N) ratios for a given output signal S/N ratio compared to FM. In addition, AM does not offer any capture effect to help discriminate against multipath or interference on the same frequency.

Video compression techniques have been developed which can reduce the required bandwidth for any given video channel. These techniques have been demonstrated in numerous applications including CATV, video conferencing, HDTV, etc. The use of video compression in conjunction with certain forms of digital modulation solve a particular problem when a solid state transmitter is used. In particular, it has been shown that video compression can be used to increase channel capacity for any transmission system, e.g., CATV, MMDS and standard as well as High Definition TV broadcast. The use of video compression can also be used to advantage to enable an LMDS Node transmitter to be practically implemented with solid state amplifiers as will be presently shown.

If the single-channel-per-carrier architecture described above is implemented while using existing CATV format signals, i.e., AM-VSB signals and digital channels based on 6 MHz channel spacing, i.e., one carrier every six MegaHertz, then 130 carriers are required per antenna sector for a bandwidth of 780 MHz. For a solid state transmitter, this would require 130 separate transmit channels and 130 Power Amplifiers per sector. By digitizing the video and using video compression techniques, each video channel can be reduced to a low bit rate per video channel. Then by

multiplexing many of these digital bit streams together into a single, high-speed serial bit stream (e.g., an STS-1 or STS-3) the number of RF channels can be reduced. However, this is a baseband signal which cannot be transmitted directly using LMDS. It can, however, be used to modulate a constant-envelope carrier to produce a signal which can be transmitted via LMDS. The advantage of this approach is that many video signals can be transmitted on a single carrier, e.g., 16 video channels can be transmitted on a single RF carrier at an information rate of 48 MBPS and with a rate $\frac{1}{2}$ FEC in a bandwidth of 60 MHz (or less) per RF channel. This is shown in FIG. 9. Hence, over 192 such video channels can be transmitted within the 780 MHz of bandwidth using only 12 RF carriers. This is less than $\frac{1}{10}$ the number of R.F. channels required using prior art, i.e., AMVSB and digital modulation using 6 MHz channels. Hence, video compression enables many video channels (a few) to be multiplexed onto a single RF carrier (rather than many) and still provide more video channels in the same bandwidth (i.e., approximately 50 percent more) than prior art. The pay-off for a solid-state transmitter is both obvious and substantial: less than 10 percent of the number of RF channels is required for the same number of video channels (assuming comparable modulation). Thus, video compression can be used in LMDS applications to reduce the number of required RF channels, and thus the amount of hardware, while increasing the number of video channels.

Prior art in LMDS designs has used techniques which are not compatible with digital Fiber Optic systems including but not limited to Synchronous Optical Network (SONET), ATM, and Digital Service-level 3 (DS3) transmission systems. This application shows how a solid state LMDS transmitter can interface to and be compatible with the higher speed transmission systems (SONET) and advanced switching techniques (ATM). While prior art has shown that ATM techniques can be used for video service via CATV networks, this application discloses how an LMDS system can provide video service using ATM technology. Specifically by demultiplexing complex OC-n signals down to OC-1 signals and implementing the LMDS system as a group of n parallel transmitters, a SONET-compatible LMDS system can be implemented using solid state transmitters. Such a system can provide ATM-based video service. In other words, as shown in FIG. 10, the OC-1 signals at data rate of 51.84 MBPS are multiplexed at the central office 15 and sent via fiber cables 16 (FIG. 1) to the node transmitter/receiver where they are demultiplexed and applied to separate RF carrier channels.

While the down stream digital transmission system can implement SONET/ATM formats relatively easily, the return path is much more difficult. Prior-art implementation has shown that the return channel can be implemented as either low-data-rate TDMA circuits, or as narrowband FDM circuits. The problem with either of these approaches is that they require a large number of transmitters and receivers at the node, and neither can easily provide bandwidth on demand. This invention shows how the number of transmit/receive channels at the node can be reduced and how each user can be assigned bandwidth on demand. This problem is solved by using broadband TDMA techniques in conjunction with the number of time slots assigned to a user based on demand rather than being pre-assigned.

A major limitation on the return channel is that the receive modem at the node must acquire both carrier sync and clock sync for each user's transmission. However, the nature of two-way telephony places major constraints on the maximum interval between burst transmissions. Specifically,

Plain Old Telephone Service (POTS) uses 2-wire analog transmission in the local loops. Hence echoes are returned from the far end. The time delay is a function of path length and length between samples (interval between pulse or frame transmissions in a TDMA system). The maximum time delay which can be tolerated before the echo becomes annoying is about 15 msec. Since any given circuit may involve transversal of many different multiplexers as well as long paths, the delay in any given multiplexer must be held to a minimum. The choice of cell length for ATM was set at a maximum of 53 bytes of which 48 are payload (384 bits) to minimize total path delay and hence echo effects. At 51.84 MBPS, this corresponds to about 82 microseconds per cell. A maximum of 768 DSO channels can be transported by a single OC-1 circuit. The data rate for a DSO channel is 64 KBPS. A buffer which stores data corresponding to 384 periods at 64 KBPS would create 6 msec of voice delay. This is excessive, and hence a cell is made up of more than one DSO channel, e.g., one byte from 48 channels or one byte from each channel of a digroup. This reduces the time delay to 0.125 msec for each voice circuit. This assumes that 48 such DSO circuits are available at a multiplexer; this is practical at the node but not at the customer site. Transmitting only one byte per frame is also not practical. Alternatives include: (1) Transmit a single DSO channel over a carrier; (2) Maintain sufficiently accurate clock sync so that data can be recovered with minimum overhead; (3) Use CDMA in conjunction with TDMA to allow for overlapping transmissions; (4) Use segmented cell transmission with a slotted buffer at the node receiver to reconstruct the cells. The first solution is not practical because of the large number of receivers required; the second is not practical because of variations in path parameters; the fourth is difficult to implement because of the switching time associated with turning the transmitter on and off in such a short time period (less than 0.1 microseconds) and the set-up time of the AGC on the receiver. The third approach allows the transmission time to be extended without changing the transmission rate or reducing the efficiency. However, it requires both a more complex transmitter and a more complex receiver. The following description delineates the implementation.

Each bit of each byte of each packet (cell) is encoded using a suitable code, e.g., a Walsh function having order 6 or length 64. There exist 64 such unique orthogonal codes (See FIG. 14). One of these is assigned to each of 63 channels. Each channel then transmits either code or inverted code (depending on whether the data bit is 0 or 1). The period of the code is 64 clock periods. Hence, each bit is expanded into 64 code bits or chips. Eight consecutive data bits are transmitted in succession, resulting in the transmission of 512 code bits in succession. In addition, a unique preamble is transmitted. At the same time 63 other customer units will transmit one byte of data using orthogonal codes from the Walsh function set. Hence, there will be 63 simultaneously transmitted messages having a duration of about 9.877 microseconds. Each message will be preceded by a preamble having a duration of approximately 5 microseconds. Hence, each packet or burst has a total duration of approximately 14.877 microseconds. At a data rate of 48 MBPS, this permits approximately 400 channels to be transmitted. The maximum time between samples is about 0.16 msec, well within the acceptable range.

The impact on the customer end hardware is the need to add a simple encoder to spread the data signal by a factor of 64. The impact on the node receiver is the need to provide at least 63 code correlators for each STS-1 receive channel. However, this can be implemented as a Fast Walsh Transform (FWT) if time is aligned accurately enough.

While the preceding discussion related the implementation to ATM packets and SONET rates, a similar argument can be made for DSO and DS3 formats.

The approach for the return channel is the preferred embodiment. However, it is not the only approach. Other approaches include using individual channels for each DSO or voice channel, i.e., the same as analog cellular phone service. A second approach is to use PCS format (either TDMA or CDMA technology) for the return channel. These may be implemented in either of at least two ways: (1) Simply co-locate a cellular or PCS base station with each node and a cellular or PCS phone at each customer site. (2) Use the same format at PCS (e.g., TDMA or CDMA but translated to the LMDS band for subsequent distribution to customers. At each customer site, translate the signal to the PCS band, use a built-in PCS handset function to demodulate the databand connect to wiring. (Or alternately provide a pica-cell radiator at the customer location). Approach number two has the distinct advantage of not using the PCS band for fixed telephone service as well as offering additional capacity over PCS.

OTHER EMBODIMENTS

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims.

For two-way service, time division multiplexing or code division multiplexing is used to provide Demand Assign Multiple Access (DAMA) capability. CDMA reduces the peak transmit power required at the subscriber transmitter, and hence minimal the necessary transmit-receive isolation in the subscriber equipment.

What is claimed is:

1. A transmitter system for a short range wireless point to multi-point communications system, comprising:

a transmitter operable to broadcast a plurality of channels over a given frequency band, each channel associated with a different one of a plurality of sub-frequency bands of the frequency band;

a plurality of transmitting antennas, each transmitting antenna including a plurality of linear arrays, each linear array having a plurality of radiating elements and a plurality of exciter stubs, each exciter stub being aligned with an associated radiating element, each linear array associated with a different one of the plurality of channels to broadcast information over an associated sub-frequency band of the frequency band, each of the plurality of transmitting antennas having a polarization type different than that of an adjacent transmitting antenna, wherein each exciter stub and associated radiating element are spaced to control a phase between radiating elements.

2. The transmitter system of claim 1, wherein the sub-frequency bands are contiguous to each other.

3. The transmitter system of claim 1, wherein the transmitter includes a plurality of multiplexers, each multiplexer operable to time multiplex channel information for a corresponding channel onto an output stream.

4. The transmitter system of claim 3, wherein the transmitter includes a plurality of modulators, each modulator operable to modulate the channel information for a corresponding channel.

5. The transmitter system of claim 3, wherein the transmitter includes a plurality of up-converters, each

up-converter operable to up-convert a corresponding channel to a millimeter frequency.

6. The transmitter system of claim 3, wherein the transmitter includes a plurality of encoders, each encoder operable to perform forward error correction on a corresponding channel.

7. The transmitter system of claim 1, wherein the transmitter includes a plurality of amplifier systems, each amplifier system operable to provide linear amplification to a corresponding channel in order to prevent intermodulation distortion from interfering with other channels.

8. The transmitter system of claim 7, wherein each amplifier system includes a plurality of amplifiers, each amplifier associated with a corresponding radiating element.

9. The transmitter system of claim 1, wherein the transmitter includes a compression unit operable to compress the channel information in order to reduce a number of the plurality of channels required for communication.

10. The transmitter system of claim 1, wherein information for each channel is provided by a central office.

11. A method for providing short range wireless point to multi-point communications, comprising:

receiving channel information corresponding to a plurality of channels;

placing the channel information into the plurality of channels;

associating each of the plurality of channels with a different sub-frequency band of a given frequency band;

polarizing each of a plurality of transmitting antennas such that each transmitting antenna has a polarization type which is different than a polarization type of an adjacent transmitting antenna;

aligning one of a plurality of exciter stubs with an associated one of a plurality of radiating elements in each transmitting antenna;

spacing the plurality of exciter stubs and associated radiating elements in each transmitting antenna to control a phase between radiating elements;

transmitting the plurality of channels over the plurality of transmitting antennas at the given frequency band.

12. The method of claim 11, wherein the plurality of transmitting antennas are orthogonally polarized.

13. The method of claim 11, further comprising: multiplexing the channel information onto an associated channel.

14. The method of claim 11, further comprising: modulating each channel.

15. The method of claim 11, further comprising: up-converting each channel to an appropriate millimeter frequency.

16. The method of claim 11, further comprising: amplifying each channel according to linear amplification techniques in order to prevent intermodulation distortion from interfering with other channels.

17. The method of claim 11, further comprising: compressing the channel information to reduce a number of the plurality of channels.

18. The method of claim 11, further comprising: performing forward error correction on each channel.

19. The method of claim 11, wherein the channel information is received through microwave transmission.

20. The method of claim 11, wherein the channel information is received through fiber optic transmission.

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